Analysis Of Non-Tactical Vehicle Utilization At Fort Carson

DISCLAIMER: Reference herein to any specific commercial company, product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the Department of the Army (DoA). The opinions of the authors expressed herein do not necessarily state or reflect those of the United States Government or the DoA, and shall not be used for advertising or product endorsement purposes.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **26 JUL 2012**	2. REPORT TYPE **Briefing**	3. DATES COVERED **01-06-2012 to 01-07-2012**

4. TITLE AND SUBTITLE **ANALYSIS OF NON-TACTICAL VEHICLE UTILIZATION AT FORT CARSON**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Steven Eick**	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army TARDEC,6501 East Eleven Mile Rd,Warren,Mi,48397-5000**	8. PERFORMING ORGANIZATION REPORT NUMBER **#23240**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000**	10. SPONSOR/MONITOR'S ACRONYM(S) **TARDEC** 11. SPONSOR/MONITOR'S REPORT NUMBER(S) **#23240**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Submitted to 2012 NDIA Ground Vehicle Systems Engineering and Technology Symposium August 14-16 Troy, Michigan

14. ABSTRACT
Department of Defense (DOD) is considering integration of electric vehicles into its non-tactical vehicle (NTV) fleet to support efficiency goals and sustainable power initiatives.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Public Release**	**19**	

Need for Duty Cycle Analysis

- Department of Defense (DOD) is considering integration of electric vehicles into its non-tactical vehicle (NTV) fleet to support efficiency goals and sustainable power initiatives
  - DOD owns/operates nearly 200,000 NTVs worldwide
- In order to identify the best vehicles for electrification, DOD needs to understand the duty cycles and daily operating patterns of NTVs on bases
  - Mileage logs exist for the NTV fleet, but total mileage over time does not provide enough information to identify electrification candidates
  - Granular information on vehicle location vs. time plus driving profiles are desirable to understand electrification potential
  - Need to know if daily mileage exceeds PEV range, and whether stopovers occur where recharging would be possible

Duty Cycle Development

- Six-month data acquisition study on Fort Carson NTV fleet was conducted in 2011-12, funded by TARDEC
  - 24 vehicles representing a variety of NTV types and uses monitored for ~ two weeks each
  - Two types of data loggers utilized:
    - TranSystem 747ProS -- Low-cost, non-intrusive GPS data logger with vibration sensor and power-on triggers (<$100)
    - IOSiX OBD-II Port Data Logger with GPS module -- Used on some vehicles to obtain additional CAN data regarding key-on, engine idle time and fuel efficiency (<$1000)

  - Data was retrieved manually at end of each two-week period and processed using MATLAB algorithms developed for this project
    - Large data set size -- array length ranges from 100,000 to nearly one million
    - MATLAB also used to generate geo-plots for OBD-II logger data

Duty Cycle Development – Cont.

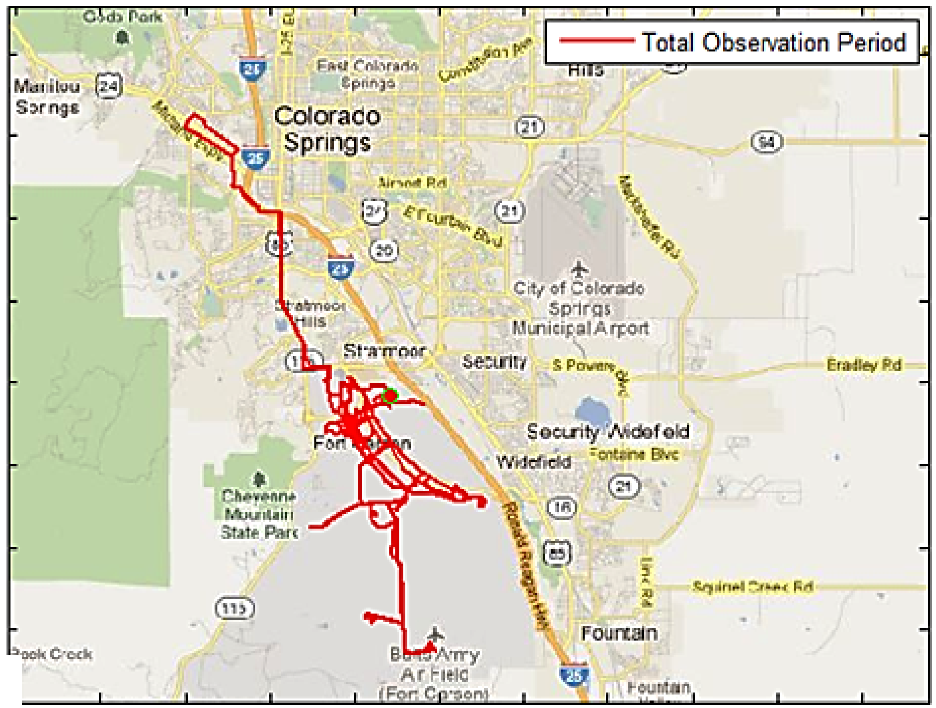
MSTV
MODELING AND SIMULATION, TESTING AND VALIDATION

- Information extracted on vehicle utilization from data acquired
  - Usage days, trips per day, time and distance for each trip, speed profiles, acceleration and deceleration percentage, idle time
  - Geographic route diagrams generated for each trip from GPS data using mapping software
- Standard Summary Report developed to display key utilization profile metrics
  - Utilization metrics displayed in standard table
  - Overall route diagram for two-week monitoring period displayed
  - Usage statistics for daily mileage, time, and number of trips plus speed profile presented in graphical form
  - Vehicle speed trace for full monitoring period included

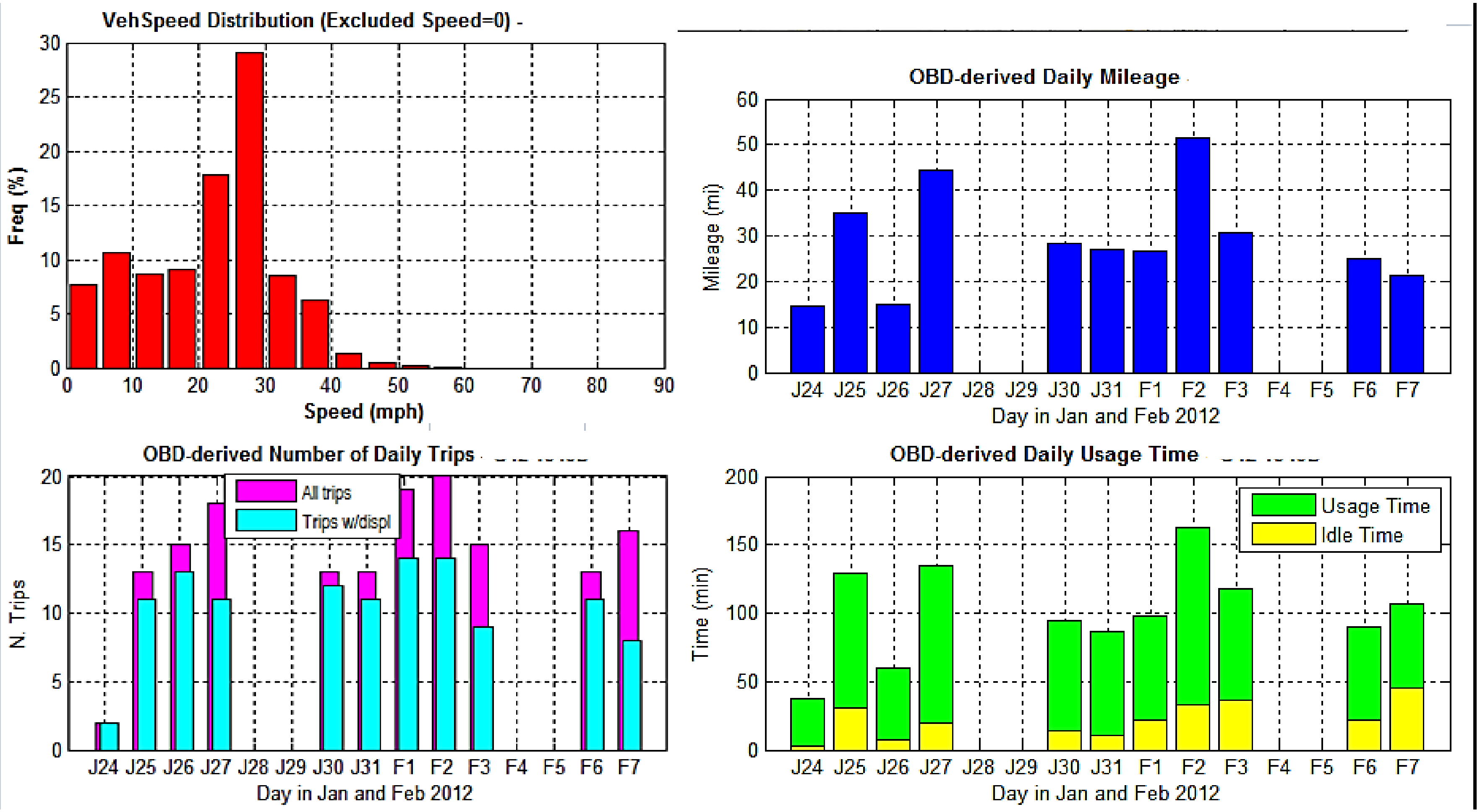
Utilization Summary Report – Usage Metrics + Route Map

	Observation Period 24-Jan-12 to 7-Feb-12	Work Truck - F 150
Total Mileage (mi)	319	
Highest Daily Mileage (mi)	51.3	
Observation Time (dd)	15	
N. Days of Utilization	11	
Utilization Time(hh:mm)	18:38	
Time at Speed (hh:mm)	14:37	
% Idle Time	22%	
Average Speed (mph)	21.8	
%Time Speed>=40 mph	2%	
N. Total Starts	157	
%Accel Time	15%	
% Decel Time	15%	
% Cruise	48%	

Geo Maps All Days - 24 Jan to Feb 7 2012



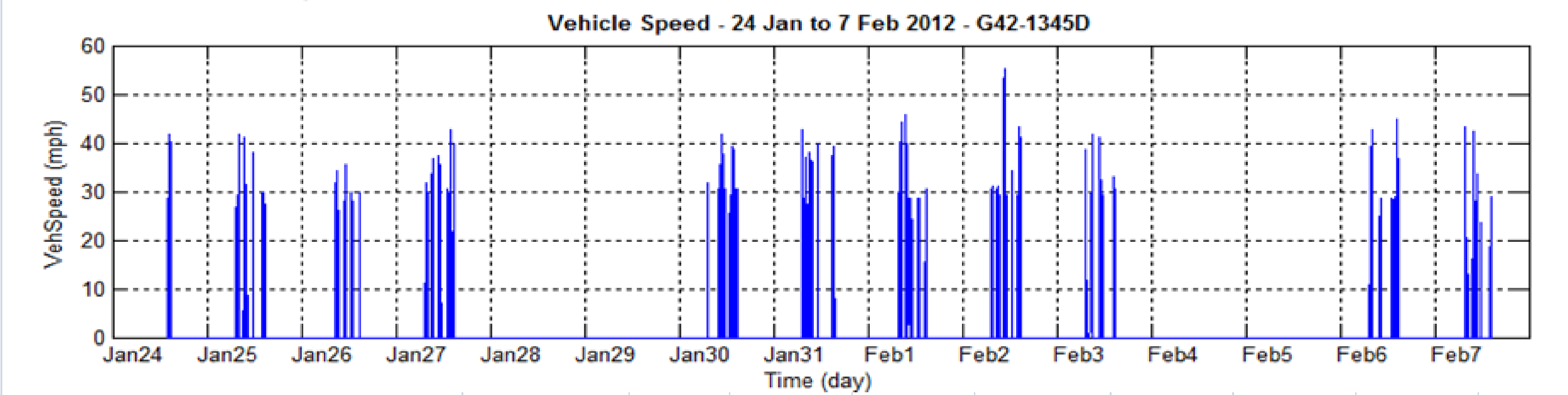
Utilization Summary Report – Graphical Displays



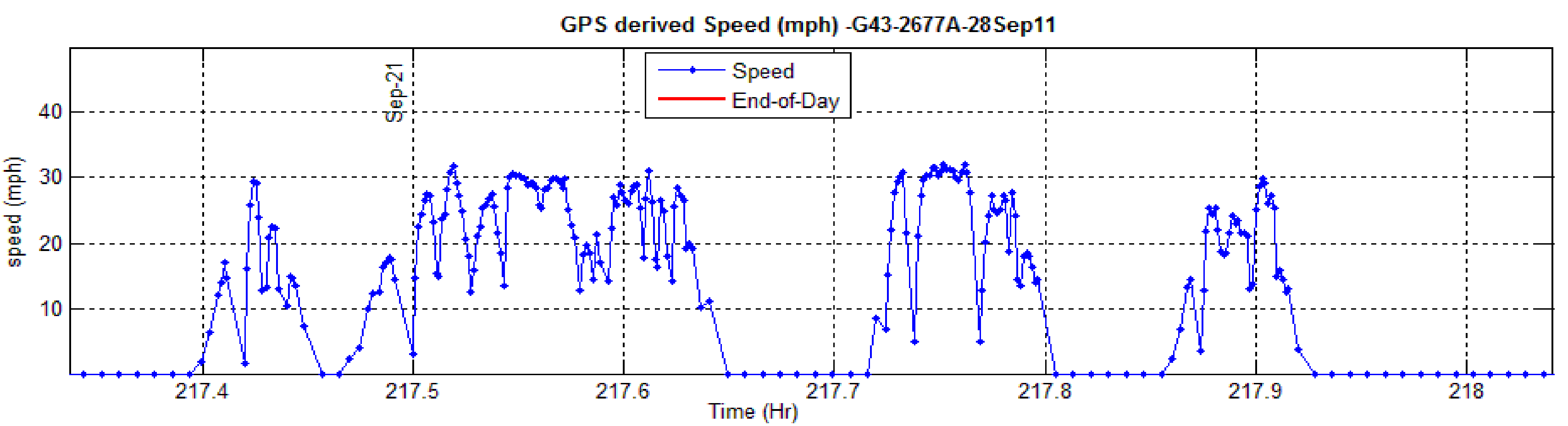
Utilization Summary Report – Vehicle Speed Trace vs. Time

MSTV
MODELING AND SIMULATION, TESTING AND VALIDATION

- Summary report includes Speed vs. Time plot for full 14-day monitoring period



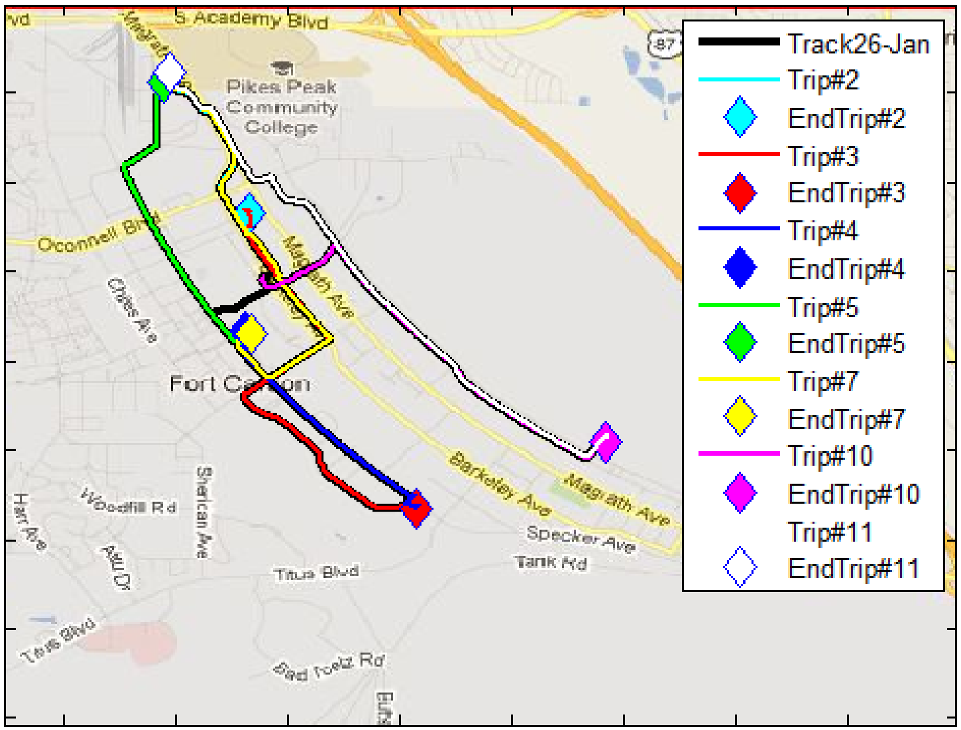
- 30-Minute segment amplified

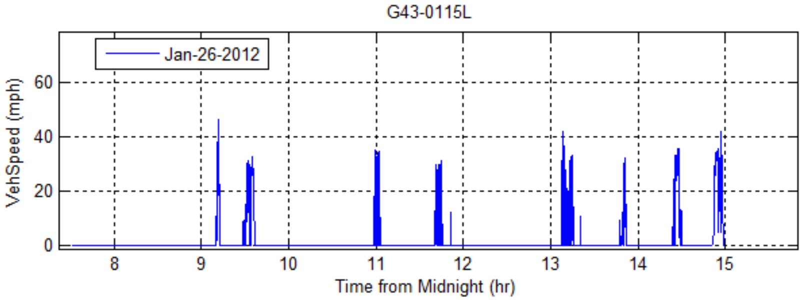


Individual Trip Route Plots

- Summary report shows two-week route plot, but daily individual trip plots also provided for select vehicles to better understand usage

Daily Geo Map - G43-0115L





26-Jan-12		
TripN (#)	Duration (sec)	Distance (mi)
1	356	0.0
2	291	1.1
3	457	2.2
4	309	1.3
5	333	1.6
6	45	0.1
7	732	2.2
8	11	0.0
9	297	0.6
10	387	2.1
11	530	2.9

Trip Statistics

- Statistical analysis used to generate more meaningful metrics to compare vehicle driving profiles
  - Summary metrics of trip distance, length and maximum speed are too granular to perceive trends between vehicles
  - Mean and median of trip distance and duration (time) over the two-week monitoring period provide desired level of detail

Statistical Analysis Table

Work Truck	N. Trips	153
	N. Trips>0.2 mi	135
Param	**Time(sec)**	**Distan(mi)**
average	430.4	1.7
median	385	1.5
1st Quartile	229	0.3
3rd Quartile	552	2.4
Max	1734	6.9
Min	4	0

- Distance travelled in 25% of trips is ≤ 0.3 miles with average trip time of just under 4 minutes
- Distance traveled during 50% of the trips (median value) is ≤ 1.5 miles with an average trip time of approximately 6.5 minutes
- Average values of time and distance are larger than the median values which points to the existence of some longer trips, however, maximum trip distance is still relatively short at only 6.9 miles.
- Thus, this vehicle would likely be a good candidate for electrification.

NTV Utilization Data Summary by Vehicle Type

MSTV
MODELING AND SIMULATION, TESTING AND VALIDATION

Function	No. Util. Days	Time at Speed (hh:mm)	Total Mileage (mi)	Highest Daily Mileage (mi)	Percent Idle Time (%)	No. trips	Avg Spd (mph)	Operational Location
Engineering	12	13:17	226	36	23	94	22.5	Base/City
Maint/Supply Activ	9	8:40	244	67	15	65	28.5	Base/City
Maint/Supply Activ	10	9:06	193	37	14	97	21.0	BaseCtr
DPW Fleet Mgr	11	8:34	171	38	26	93	19.9	BaseS/City
Maintenace	11	18:54	694	111	30	74	37.6	Base/City
Pool	11	27:24	1491	314	11	147	54.5	Base/South
Pool (Exec. Van)	7	15:41	958	332	6	42	61.3	Base/NM
Work Truck	15	21:28	494	54	12	165	23.2	Base/South
Work Truck	7	6:06	184	73	20	78	30.0	Base/South
Work Truck	13	12:16	253	30	33	153	20.6	Base
Work Truck	11	9:25	199	66	11	113	21.4	Base/BaseSo
Work Truck	11	14:37	319	51	22	157	21.8	Base/City
Work Truck	11	8:36	215	66	17	79	25.0	Base/BaseSo
Delivery Flat Bed	8	3:18	58	16	19	52	17.8	Base
Work Truck	9	6:28	116	42	18	70	18.1	Base/City
Ambulance	17	15:15	372	52	10	116	30.5	Base/City
Ambulance	8	12:36	394	102	23	142	30.6	Base/City
Ambulance	14	22:08	789	217	42	85	35.6	Base/Pueblo/Denver
Ambulance	15	23:01	669	88	48	102	29.0	Base/BeaverCr./City
Ambulance	15	23:12	778	145	14	166	33.6	City/Pueblo
25-Psgr Bus	1	5:56	273	273	2	7	47.3	WestRange
25-Psgr Bus	3	12:10	546	286	38	10	44.8	Mountains
Transport Bus	5	4:29	90	34	16	60	20.2	Base/City
25-Psgr Bus	9	38:40	1761	290	53	34	45.5	Mountains

Summary Trends by Vehicle Functional Type

- **Support Vehicles: Engineering, Maintenance & Supply, DPW Fleet Mgr.** – Utilized nearly every work day on the base or in the adjacent city area but rarely on weekends or for longer trips. Average daily mileage was 16 – 27 mi for four of the vehicles with an average speed below 30 mph, so this group appears to contain good candidates for electrification.
- **Pool Vehicles** – Usage varied considerably with short-distance, low-speed trips on some days and long-distance, high-speed trips on others. This suggests there is an opportunity to have some pure EVs as pool vehicles for local trips plus a mix of PHEVs or charge-sustaining HEVs for longer trips.
- **Work Trucks** – These box trucks on a light or heavy-duty pickup chassis are used to transport an operator and tools to on-base locations for maintenance and repair. They make frequent short trips with low total daily mileage and normally return to their primary storage location, making these the best candidates for electrification of the vehicle types examined.

Summary Trends by Vehicle Functional Type

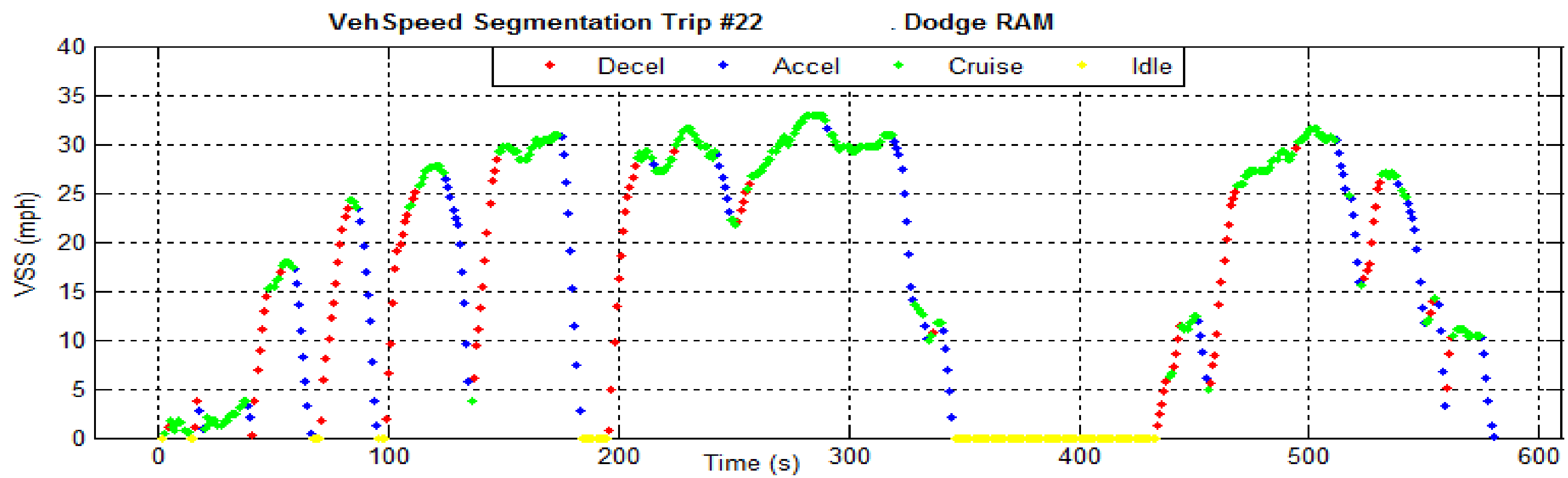
MSTV
MODELING AND SIMULATION, TESTING AND VALIDATION

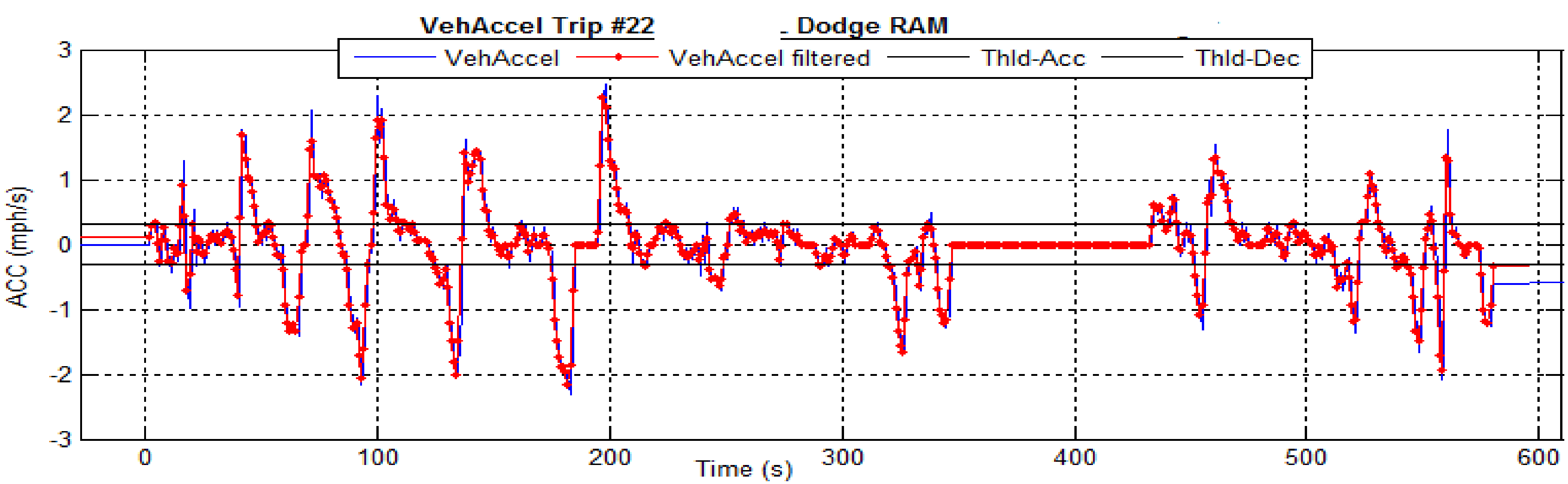
- **Ambulances** – Tend to be used seven days per week but daily trip count and mileage vary significantly and include some high-speed, long-distance trips. Idle time can also be high due to the need to power on-board equipment during a deployment. As a result, electrification potential is low.
- **Transport and Shuttle Buses** – A Bluebird transport bus used on or around the base averaged 12 trips per day with low total mileage, making it a good electrification candidate. The shuttle buses monitored were used for much longer trips, including overnight and at high speeds, meaning they would be more difficult to electrify.

Energy Recovery Potential

- Electrified vehicles rely on the translation of kinetic energy into electrical energy for recovery into a storage mechanism (regeneration) as a key element of their overall efficiency
  - The potential kinetic energy available for recovery is thus an important consideration in vehicle electrification decisions
  - In this study, neither the mass of the vehicles monitored nor the payload they typically carry was known, so kinetic energy could not be calculated directly
- From the available GPS data, deceleration profiles were analyzed to extract a metric from which to estimate energy recovery potential
  - The metric produces a distribution of the changes in unit time of the square of the vehicle velocity (VSS2) which is proportional to kinetic energy loss (power) once the appropriate constant for the mass is factored in
  - This method means extracting from each braking event equivalent segments from an energy perspective, regardless of the initial value of the vehicle velocity
  - This allows vehicles of similar mass to be qualitatively compared assuming they operate on similar drive cycles

Accel/Decel Profile

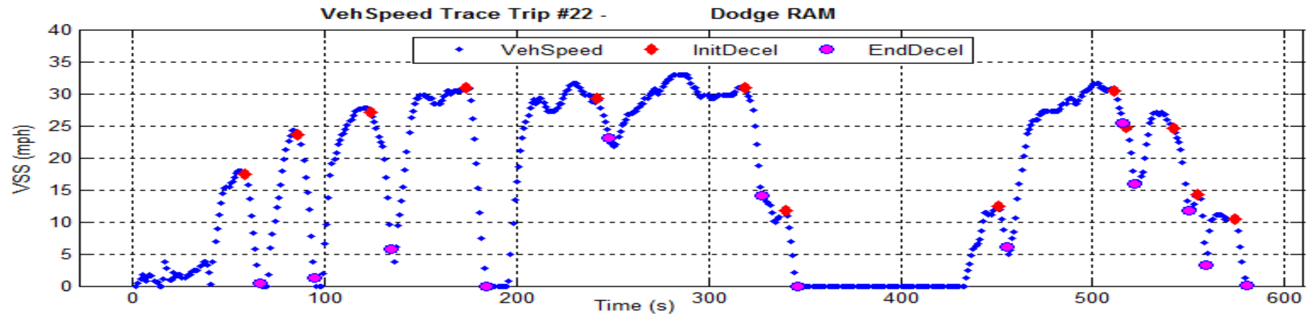


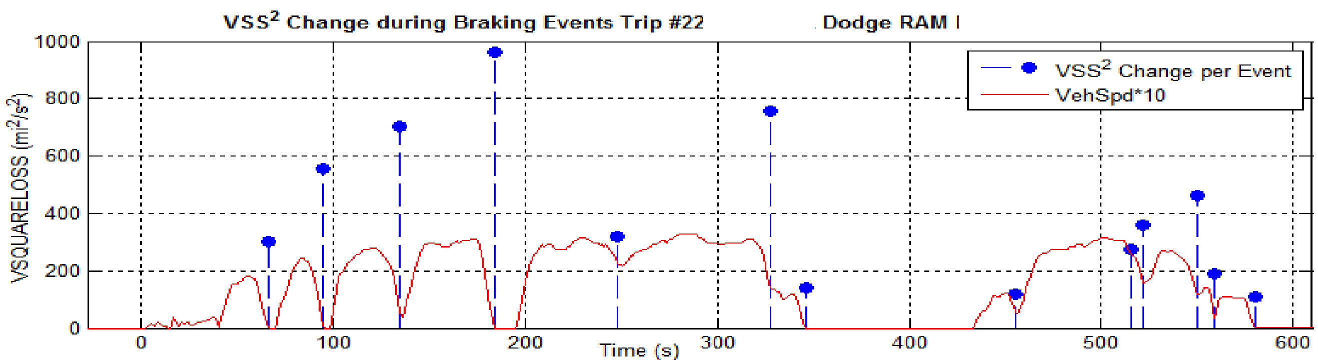


Deceleration Profile Analysis

MSTV
MODELING AND SIMULATION, TESTING AND VALIDATION

- The Kinetic Energy change during a braking event is proportional to the difference of the initial velocity square and final velocity square ($\Delta\ VSS^2$)
  - Stem plot at bottom gives values proportional to the change of Kinetic Energy during each event -- braking events starting at higher speeds produce larger energy changes
  - An estimate of the upper limit for energy that can be harvested during a Trip (or entire driving cycle) is proportional to $VSquareLoss = \sum_n (Vin_n^2 - Vfin_n^2) = \sum_n \Delta\, VSS^2$ where n counts braking events over the cycle

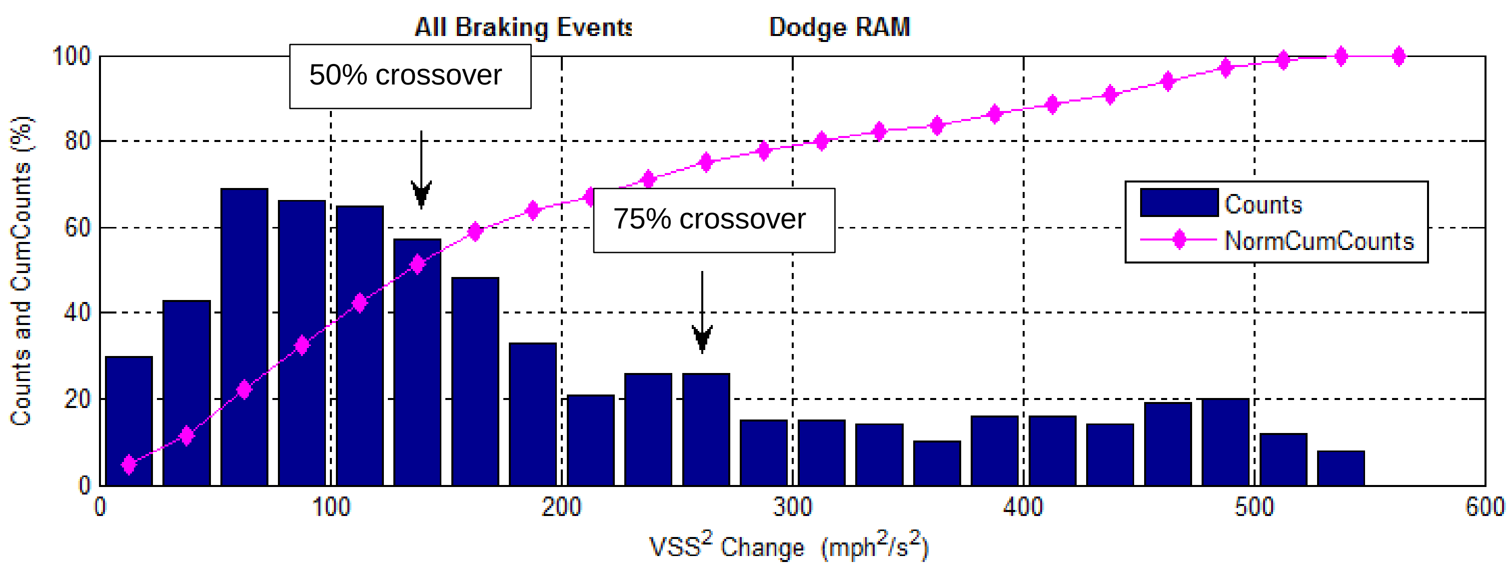




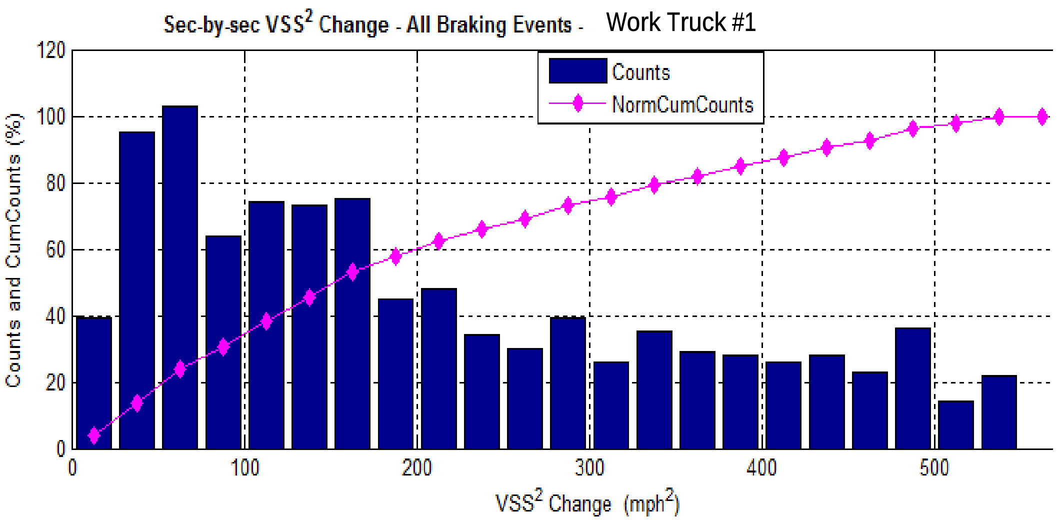
GVSETS
NDIA Michigan Chapter National Defense Industrial Association

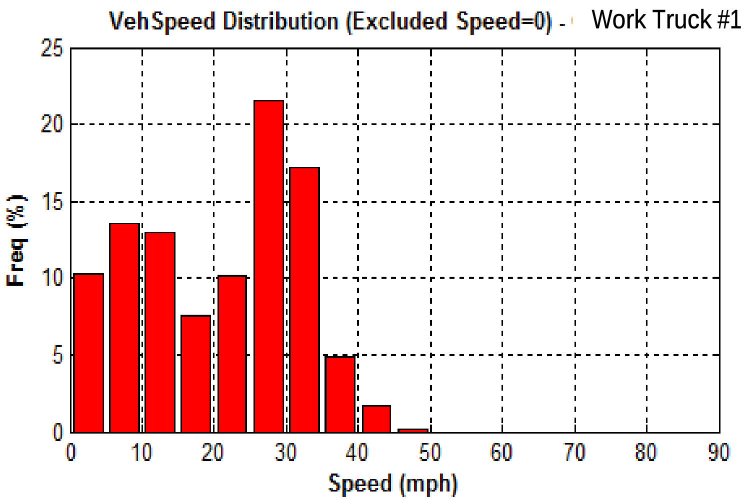
Regeneration Benefit Comparison Metric

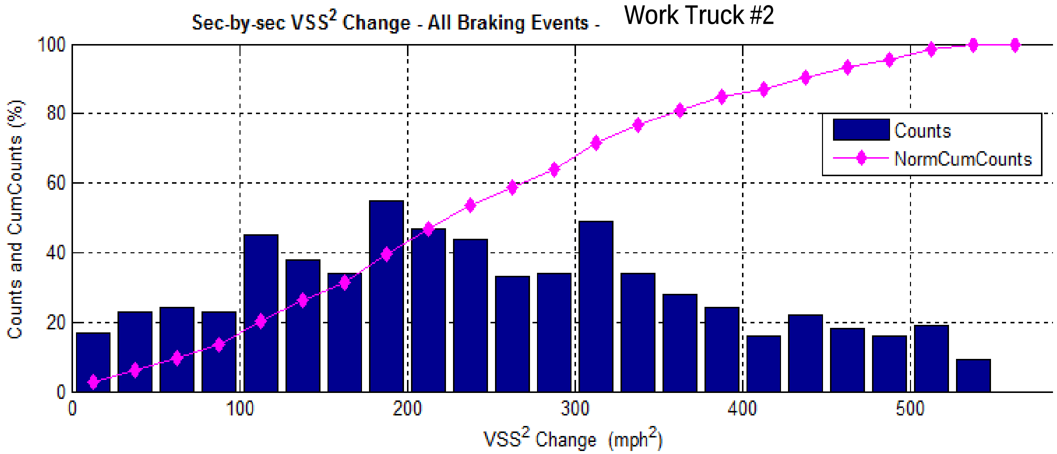
- This leads to another metric for evaluating potential regeneration benefits
  - A histogram of all Braking Events during the vehicle's observation period has been constructed by binning events on ΔVSS^2
    - Distribution is given in Counts, not Percentages
  - Pink trace shows cumulative sum of Event numbers normalized to 100%
  - Bin corresponding to either 50% or 75% crossover can be used as comparison metric to other vehicles (if mass is normalized) or other drive cycles

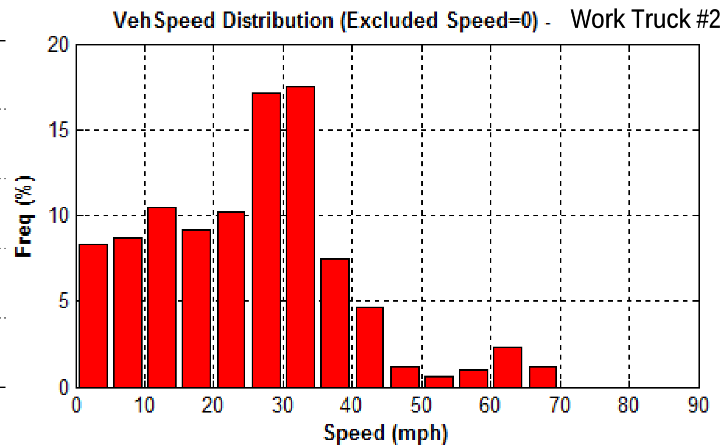


Regeneration Benefit Comparison – Work Trucks









Conclusions

- A variety of non-tactical vehicles at Fort Carson were monitored for two-week periods to extract duty cycle and geographic usage information
  - Data was acquired utilizing either low-cost GPS data loggers with vibration sensor activation or OBD-II port data loggers with GPS capabilities
  - Data series were taken which enabled statistical analysis of the driving profile plus evaluation of driving routes and characteristics on a daily basis
- Vehicles were categorized by usage type and conclusions made regarding suitability of each type for conversion to electrified vehicles
  - Conclusions derived by examining daily trip statistics along with percent idle time, speed profiles, and the distance vehicles traveled away from potential recharging points during a single day
- Further analysis is required to determine whether the Fort Carson NTV duty cycle results are applicable to NTV fleets at other military bases
  - Could provide guidance as DOD ramps up fleet electrification plans

Conclusions – Cont.

- NTV duty cycle data generated will be used for comparison to electrified vehicles being added to Fort Carson fleet
  - Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) Phase II Demonstration Project at Fort Carson will utilize this data
- Deceleration data obtainable with a simple GPS data logger can also be analyzed to provide a useful indicator of kinetic energy recovery potential in an electrified vehicle
  - Methodology employed utilized frequency and severity of deceleration events coupled with vehicle speed profile to provide a comparative analysis tool